Faculty of Manufacturing Engineering

PREPARATION & CHARACTERIZATION OF ELECTROPHORETICALLY DEPOSITED BN FILM FOR SEMICONDUCTOR PACKAGE

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Master of Science in Manufacturing Engineering

2017

PREPARATION & CHARACTERIZATION OF ELECTROPHORETICALLY DEPOSITED BN FILM FOR SEMICONDUCTOR PACKAGE

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this thesis entitled “Preparation & Characterization of Electrophoretically Deposited BN Film for Semiconductor Package” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : ……

Supervisor Name : ……

Date : ……

DEDICATION

To my beloved family, lecturers and friends.

ABSTRACT

Boron Nitride (BN) is used in various applications such as in lubrication, as a releasing agent and also as a thermosetting insulator material and thermal enhancer because of its advanced material properties. Electrophoretic deposition (EPD) method is a new method for semiconductor industries and it has grown in the interest on making use of BN as a thermal interface material and electrical isolation in Transistor Outline (TO) packages. Hexagonal Boron Nitride (h-BN) stability in EPD suspension is essential to produce repeatability and reproducibility in the result of the deposition. However, h-BN particle has less functional group on its side wall to create bonding with the polymer matrix. In order to increase functional groups on its side wall, NaOH surface treatment which has been established by other researchers was performed. The purpose of this study is to prepare and characterise of the h-BN particles in EPD suspension using different types of suspension mediums and binders. The particle size characterization and Field-Emission Scanning Electron Microscopy (FESEM) on the as-received h-BN particle indicates that particle sizes were less than 1 μm but are in agglomerated forms in the De-ionized (DI) water suspension. Sedimentation test method of h-BN particles in four dispersion media (deionized water, Acetic acid solution, Sulphamic Acid & Ammonia) and using different binder (Polyethylene Glycol (PEG), Silane Coupling Agent, Polycationic 1 (PC 1), Polycationic 2 (PC 2). The result showed a combination of deionized water and PC 2 produced the highest stability for h-BN dispersion. Sedimentation test and zeta potential method were used to determine the optimum concentration of PC 2 addition in a h-BN suspension. EPD of h-BN was performed on TO package using different levels of PC 2 concentration (i.e. 0.2 – 1.0 wt%). Characterization of the EPD coating were performed in terms of thickness, microstructure analysis on surface and micrograph from FESEM, and surface roughness. The optimum concentration of PC 2 in order to achieve the highest h-BN stability was in the range of 0.3 – 0.4 wt%, with a corresponding deposition thickness of 8 μm. The obtained thickness was the highest among other samples, and had surface roughness of 570 nm. Critical factors that affected the deposition for h-BN EPD process were suspension ionic conductivity and excess PC 2 concentration. High conductivity and excess PC 2 concentration caused electric double layer of h-BN particles to be compressed thus resulting in a low deposition yield. Therefore, it is recommended that future works use ultra-pure DI water and excess binder of h-BN suspension need to be removed by centrifugal washing before undergoes EPD to reduce conductivity of h-BN suspension. Besides it also helps to achieve a high deposition thickness of h-BN for thermal conductive and electrical isolation application.

ABSTRAK

Boron Nitride (BN) digunakan dalam pelbagai aplikasi seperti dalam pelinciran, sebagai ejen pelepasan dan juga sebagai bahan penebat haba serta pengkonduksian haba kerana sifat-sifat bahan termajunya. Kaedah penyaduran electrophoretik (EPD) adalah satu kaedah baru bagi industri semikonduktor, maka terdapat peningkatan minat ke atas penggunaan BN sebagai bahan antaramuka haba dan penebatan elektrik dalam pakej TO. Kestabilan heksagon Boron Nitride (h-BN) dalam ampaian EPD adalah penting untuk membolehkan pengulanngan dan penghasilan semula data penyaduran. Walau bagaimanapun, zarah h-BN mempunyai sedikit kumpulan berfungsi pada permukaan sisi untuk mewujudkan ikatan dengan matrik polimer. Dalam usaha untuk meningkatkan kumpulan berfungsi pada dinding sisi, rawatan permukaan NaOH telah dilakukan sepertimana yang telah diwujudkan oleh penyelidik lain. Tujuan kajian ini adalah untuk menyedia dan menciri zarah h-BN dalam ampaian EPD menggunakan jenis media ampaian dan pengikat berlainan. Pencirian saiz zarah dan Pengimbas Elektron Mikroskop (FESEM) ke atas zarah h-BN mentah menunjukkan saiznya kurang daripada 1 mikron tetapi dalam bentuk gumpalan di dalam ampaian air ternyahion (DI). Kaedah ujian pemendapan zarah h-BN dalam media ampaian berbeza (air ternyahion, pelarut asetik asid, acid sulfamic & Ammonia) dan menggunakan pengikat yang berbeza (poli etilena glikol (PEG), ejen Silane gandingan, Poli kationik 1 (PC 1), Poli kationik 2 (PC 2)) menunjukkan kombinasi air ternyahion dan PC 2 menghasilkan kestabilan paling tinggi berbanding dengan kombinasi medium ampaian dan pengikat lain bagi h-BN. Ujian pemendapan dan kaedah keupayaan zeta telah digunakan untuk menentukan kepekatan PC 2 optimum perlu ditambahkan ke dalam h-BN ampaian. EPD daripada h- BN telah dilakukan ke atas pakej menggunakan tahap kepekatan PC2 berbeza (i.e. 0.2-1.0 wt%). Pencirian saduran EPD termasuk ketebalan, analisis mikrostruktur pada permukaan dan keratan rentas menggunakan FESEM, dan kekasaran permukaan. Kepekatan optimum diperlukan oleh PC 2 untuk mencapai kestabilan tertinggi ialah dalam julat 0.3-0.4 wt%, dengan ketebalan penyaduran berkenaan pada 8 µm. Ketebalan penyaduran yang tertinggi mempunyai kekasaran permukaan sebanyak 570 nm. Faktor kritikal yang memberi kesan kepada penyaduran h-BN EPD adalah kekonduksian ionik dan kepekatan PC 2 berlebihan di dalam ampaian. Faktor ini menyebabkan dwi-lapisan elektrik zarah h-BN dimampatkan, mengakibatkan hasil penyaduran yang rendah. Maka, penyelidikan akan datang disyorkan menggunakan air DI ultra tulen, serta agen pengikat berlebihan bagi ampaian h-BN perlu diemparkan sebelum proses EPD. Kaedah ini akan menyumbang kekonduksian yang rendah, serta membantu mencapai ketebalan penyaduran h-BN yang tinggi untuk aplikasi konduksi haba dan penebatan elektrik.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my supervisor Dr. Lau Kok Tee from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his supervision, support and dedication towards the completion of this thesis. I would remember the quotes that he had always mentioned to me "Never give up" and this has given me the strength to withstand and to overcome all the challenges throughout the journey of completing my thesis. Furthermore, I would like to express my sincere acknowledgement to Dr. Muhammad Zaimi Bin Zainal Abidin, co-supervisor of this project for his advice and suggestions as well as for following up with me throughout the research activities. I would also like to express my deepest gratitude to the management of Infineon Technologies Sdn Bhd for providing me the financial support throughout this research. Special thanks to my mentor and facilitator, Mr. Chan Chee Ling and Mr. Yong Wae Chet, and also my superiors, Mr. Vigneswaran and Ms. Tan Sock Yan for their advice and guidance. My Appreciation also goes to Mr. Asok Kumar, Mr. Jagen, Ms. Low Hwee Yin, Mr. Syahir Abd Hamid, Mr. Prabahar, Mr. Naarayanan, Ms. Lim Lay Yeap, Ms. Ng Wan Yee, Mr. Charles Low Khai Yen, Ms. Tham Moong Sin and Ms. Goh Jia Yi for the their support and to Mrs. S. Indra Devi for her help in proof-reading the thesis. To my beloved family, my mother Vally, my wife Sathiya, and my daughters, Anithra, Mishalni and Vinishaa, special thanks to all of you for your understanding and for providing me the moral support while I completed this master degree.

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LIST OF ABBREVIATIONS,

SYMBOLS AND NOMENCLATURE

μ	-	Electrophoretic Mobility
μL	-	Micro Litre
μm	-	Micro Meter
μS/cm	-	Conductivity Unit
A	-	Ampere
A	-	Surface Area
Al	-	Aluminium
Al_2O_3	-	Aluminum Oxide / Alumina
AlN	-	Aluminium Nitride
amu	-	Average Molecular Weight
B	-	Boron
B_2O_3	-	Boron Trioxide
$BaTiO_3$	-	Barium Titanium Oxide
BCP	-	Biphasic Calcium Phosphate
BD	-	Breakdown
BDV	-	Breakdown Voltage
BJT	-	Bipolar Junction Transistors
BN	-	Boron Nitride

C	-	Carbon
C	-	Celcius
C/W	-	Temperature Resistance Unit
CaO	-	Calcium Oxide
c-BN	-	Cubic Boron Nitride
CH_3	-	Methyl Group
CHO	-	Aldehyde group
Cl	-	Chlorine
cm^2	-	Centi Meter Square
cm^{-3}	-	Centi Meter Cubic
CN	-	Cyanide Functional Group
DB	-	Dielectric Breakdown
DI	-	Deionized Water
E	-	Electric Field Strength
EC	-	Electrical Conductivity
EDX	-	Energy-dispersive X-ray spectroscopy
ELD	-	Electrolytic Deposition
EPD	-	Electrophoretic Disposition
eV	-	Electron Volt
f(Ka)	-	Henry's Function
Fe_2O_3	-	Ferum Oxide
FET	-	Field-effect Transistors
FTIR	-	Fourier Transform Infrared Spectroscopy
g	-	gramme

gm/cm^3	-	Density unit
GPa	-	Giga Pascal
H^+	-	Hydrogen Ions
H_2O	-	Water
HA	-	hydroxyapatite
h-BN	-	Hexagonal Boron Nitride
HCl	-	Hydrochloric Acid
HNO_3	-	Nitric Acid
IC	-	Integrated Circuit
IEP	-	Isoelectric Point
IGBT	-	Insulated Gate Bipolar Transistor
IhBN	-	Isocyanate – Hexagonal BN
K	-	Kelvin
kHz	-	Kilo Hertz
kV	-	Kilo Voltage
kV/mm	-	Dielectric Strength Unit
kV/s	-	Kilo Voltage per Second (Voltage Breakdown)
M	-	Molarity
mA	-	Mili Ampere
mA/cm^2	-	Curent Density Unit
Mg	-	Magnesium
mg	-	Mili gramme
MgO	-	Magnesium Oxide
Min	-	Minute

ml	-	Mili Litre
mm	-	Mili Meter
MOS	-	Metal Oxide Semiconductors
MOSFET	-	Metal Oxide Semiconductor Field-effect Transistors
mS	-	Mili Siemens
mS/cm	-	Conductivity Unit
mV	-	millivolt
N	-	Nitrogen
Na	-	Natrium
NaOH	-	Natrium Hydroxide
NH_2	-	Amine Functional Group
NH_3	-	Ammonia
NH_4	-	Ammonium
Ni	-	Nickel
nm	-	Nono Meter
NTR	-	Non-treated
O_2	-	Oxygen
OH	-	Hydroxyl Functional Group
OhBN	-	Organized Hexagonal BN
PAA	-	Polyacrylic Acid
PC 1	-	Polycationic 1
PC 2	-	Polycationic 2
PCB	-	Printed Circuit Board
PDADMAC	-	Poly(Diallyldimethylammonium Chloride)

PEG	-	Poly Ethylene Glycol
PEI	-	Polyethylene Imine
PVA	-	Poly Vinyl Alcohol
PZT	-	Lead Zirconate Titanate
R^2	-	R Square
r-BN	-	Rhombohedral Boron Nitride
Rth	-	Temperature Resistance
SEM	-	Scanning Electron Microscopy
SiO_2	-	Silicon Dioxide
Si-OH	-	Silanol Functional Group
SnO_2	-	Stanum Oxide
t	-	Time
TC	-	Thermal Conductivity
TEOS	-	Tetraethyl Orthosilicate
Ti-6Al-4V	-	Titanium – Aluminium – Vanadium
TIM	-	Thermal Interface Material
TiO_2	-	Titanium Dioxide
TO	-	Transistor Outline
TR	-	Treated,
UPS	-	Uninterruptible Power Supply
V	-	Particle Velocity
V	-	Voltage
W	-	Waat
W	-	Weight